

**A MULTILEVEL TEXTURE PROCESSING METHOD FOR MAPPING  
MULTIPLE IMAGES ONTO 3D MODELS**

**BACKGROUND OF THE INVENTION**

**Field of Invention**

5       The invention relates to a texture mapping process for 3D models for mapping images onto a 3D model. In particular, the invention is a multilevel texture processing method that processes images at the image level, the texture level, and then the pixel level and adjusts image pixel intensity on the texture.

**Related Art**

10      The texture mapping technology is used to increase the reality of computer generated images (CGIs) in the field of computer graphics. Through realistic images, the texture mapping technique provides better image rendering effects with fewer polygons of the 3D models. With the advance in integrated circuit (IC) designs, the operating functions and texture memory required for texture mapping have been incorporated into most of the  
15      graphic acceleration chips. Therefore, one can find many examples that use texture mapping to generate photo-realistic images in different kinds of applications, such as games, animations, and 3D websites.

20      Generally speaking, to obtain a textured 3D model, one has to construct a complete and accurate digital 3D model of the object manually or by 3D scanning. The next step is to take 2D images of the object and to establish projection relations between the 3D model and the 2D images. After obtaining the 3D model of the object and the projection relation between it and some perspective image, we can project the digital 3D model onto a 2D image through the projection relation. In this manner, the image areas covered by the polygons in the 3D model are set to be the textures corresponding to the polygons. This  
25      completes the settings of the texture mapping.

When mapping the texture of an image to a 3D model, we can use the above-mentioned procedure to rapidly complete the settings of texture mapping, obtaining a textured model. However, an image is not sufficient to cover the texture of the whole surface of the object. In this case, the rendering of the model has a crack or a shading problem. Consequently, 5 one needs images from different perspectives to completely determine the texture in each plaquette of the 3D model. When taking images of an object from different perspectives, there may be different rendering in colors for the same point on the object surface due to the facts that pictures are taken at different times, different light sources are used, and different camera settings (zooming, focus, camera position) are made. Such differences will result 10 in variations in the texture of a digital 3D model, showing visual defects in the image rendering.

To solve this problem, we can use a predetermined 3D model texture mapping to generate a global map through projections, such as projecting onto a cylindrical or spherical surface. The pixel color variations in each area are then adjusted manually or using 15 existing image processing software such as PhotoImpact© and PhotoShop©. However, this work still requires a lot of time for a person familiar with image processing tools. For example, in the U.S. Pat. No. 6,057,850, a method has been proposed to use a lighting system that can be controlled and positioned to take images of an object with different lighting conditions. Finally, the images with fixed camera positions but different lighting 20 conditions are stitched together. This is achieved by performing different levels of intelligent pixel-wise blending according to the lighting condition and the camera position. In this manner, shades due to different lighting conditions are eliminated by averaging according to their weights, providing an image with less dependence on the light sources. Afterwards, textures are cut from this image and put into the 3D model. This method 25 allows one to rebuild a new image using different lighting conditions and camera positions. Nevertheless, it requires a special lighting system with the positioning function to obtain a better effect.

On the other hand, the U.S. Pat. No. 6,281,904 divides the 3D model into several different planar areas. The user manually selects a corresponding projection region in an image for each region on the 3D model. In different images, the projection regions for the same region on the 3D model are mixed together using various methods. This method  
5 concerns with how to synthesize the same region from different images but does not deal with differences among regions. To improve the situation, the U.S. Pat. No. 6,469,710 proposes the concept of alpha blending. The contribution of each pixel in the projection regions of different images for the same 3D model surface region to the final texture is determined. If there are images of other objects in the projection region, the contribution  
10 of this pixel is set to be zero, eliminating effects of erroneous pixels. However, the operation is the projection of the same 3D model surface region. The texture variation among regions will still have different visual effects.

## SUMMARY OF THE INVENTION

In view of the foregoing, the invention provides a multilevel texture processing method  
15 for mapping multiple images onto 3D models. Using this method, the textures of neighboring plaquettes do not have discontinuous variations in the pixel intensity due to different lighting conditions and camera parameter settings. This preserves the photo-realistic quality of the computer-generated image (CGI).

The disclosed method mainly divides the image mapping process into three levels: the  
20 image level, the texture level, and the pixel level. The pixel intensity in each level is adjusted at different strengths. At the image level, the pixel intensity of overlapped plaquettes is computed by weighted average, and the whole image is adjusted accordingly. The adjustments at the texture level use predetermined conditions to take one of the textures in the overlapped plaquettes or a normalization operation to compute the required  
25 texture. It further blurs the textures of neighboring plaquettes so that it becomes smoother. Finally, the pixel-level step processes the colors of pixels inside the plaquettes to obtain an optimized 3D model. At the same time, the invention can perform accumulated processes

on input image data, so that no new calculations are needed when new images are entered. This can save much time in processing.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The invention will become more fully understood from the detailed description given  
5 hereinbelow illustration only, and thus are not limitative of the present invention, and  
wherein:

- FIG. 1 is a schematic flowchart of the invention;
- FIG. 2 is a flowchart for processing at the image level;
- FIG. 3 is a flowchart for processing at the texture level;
- 10 FIG. 4 is a schematic view of the neighboring plaquettes; and
- FIG. 5 is a flowchart for processing at the pixel level.

### **DETAILED DESCRIPTION OF THE INVENTION**

With reference to FIG. 1, the disclosed multilevel texture processing method for mapping multiple images onto a 3D model starts by providing several images to a 3D  
15 model (step 101). The sources of the images can be obtained by taking pictures of an object from different perspectives. It does not need any special lighting system as in the prior art. Then the method determines whether the 3D model is a textured model (step 102). If the input image is the first image to be pasted on the 3D model, then the answer is obviously "no," and the texture extraction and mapping start (step 103). If the input image  
20 is not the first image, then the answer is "yes," and the image is adjusted in order at the image level (step 104), the texture level (step 105), and the pixel level (step 106). Afterwards, the method determines whether there is a following image (step 107). After all images are processed, the method outputs the 3D model (step 108). An advantage of this method is that no new calculation has to be made. Accumulated calculations can be

made and accumulated calculations can be done at any time a new image is added.

As said before, the texture extraction and mapping start when the input image is the first one to be mapped onto the 3D model (step 103). After an image and a 3D model are loaded into memory, the projection matrix of the image is first determined manually or  
5 from an automatic camera calibration procedure. Afterwards, the polygons of the digital 3D model are projected onto the real images using the projection matrix. If a polygon projected on the image is visible, then the region covered by the polygon is set to be its texture; otherwise, it is skipped and the procedure continues to the next polygon. The procedure is executed iteratively until all the polygons are processed. At this moment,  
10 since there is only a single image, there may be many blank polygons without textures attached on the 3D model.

After the 3D model is textured with the image, if there are other images to be extracted and mapped onto the model, images they are processed with the following three-level procedure, the image-level adjustments (step 104), the texture-level adjustments (step 105),  
15 and the pixel-level adjustments (step 106). Please refer to FIG. 2. Before two images are combined, the method first divides the 3D textured model and the image into projections of several polygons (step 201). Of course, the same spatial coordinates have to be used during the division transformation. The overlapped polygons are then extracted (step 202). These overlapped polygons are used to compute the statistics of the brightness of the pixels  
20 (step 203). The pixel intensity of the whole image is then adjusted according to (step 204). The formula as follows:

$$I'_s(x_i, y_i) = I_s(x_i, y_i) - \mu_s + \mu_b$$

where  $\mu_s$  is the averaged pixel intensity of the overlapped polygon on the 3D model;  $\mu_b$  is the averaged pixel intensity of the overlapped polygon of the input image;  $I_s(x_i, y_i)$  is the pixel intensity of each point on the 3D model; and  $I'_s(x_i, y_i)$  is the adjusted pixel intensity of each point on the 3D model.  
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In other words, the method uses the statistics distribution of pixel intensity of the overlapped polygons to adjust the pixel intensity of the whole image. Therefore, the pixel intensity receives a preliminary adjustment immediately after the image is entered.

After the pixel intensity of the image is adjusted, the method continues to reconfigure the texture map settings in the overlapped polygons (step 205). The adjustment is made according to the resolution, polygon orientation, viewing perspective, and so on. For example, if one uses the resolution as the determination criterion, then the polygon texture with a larger resolution can be directly used as the final polygon texture. The other conditions can be similarly applied.

10 After the image-level adjustments (step 104) and texture map reconfiguration (step 205), the method performs the texture-level adjustments to smooth the texture of the polygons. As shown in FIG. 3, the smoothing can be achieved using texture normalization (step 301) and texture blurring (step 302). The texture normalization (step 301) mainly takes the averaged pixel intensity of the texture in the overlapped polygon and feeds into  
15 the following formula:

$$T'_s(x_i, y_i) = T_s(x_i, y_i) - \mu_s + \mu_b$$

where  $\mu_s$  is the averaged pixel intensity of the overlapped polygon on the 3D model;  $\mu_b$  is the averaged pixel intensity of the overlapped polygon on the input image;  $T_s(x_i, y_i)$  is the texture pixel intensity at each point in the polygon; and  $T'_s(x_i, y_i)$  is the adjusted texture  
20 pixel intensity at each point in the polygon.

The method then performs texture blurring (step 302). The averaged intensity  $\mu_{s0}$  of the texture corresponding to each polygon is first computed (FIG. 4). The averaged intensities  $\mu_{s0} \sim \mu_{s10}$  of the surrounding polygon textures are also computed. The formula

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$$\mu'_{s0} = \sum_i w_i \mu_{si}$$

is then used to compute the destination intensity. The weight is determined using different conditions (such as distance and brightness). This makes the texture of each polygon match with its surrounding ones. The boundaries of neighboring plaquettes are thus blurred and smoothed. Of course, the polygons shown in the drawing are triangular.

5 However, any geometrical shape can be used.

Finally, step 106 performs the pixel-level adjustments. With reference to FIG. 5, an arbitrary polygon is selected (step 501). The method determines whether it has a discontinuous color variation from the neighboring polygon textures (step 502). If there is a discontinuous color change between the textures, then pixel intensity modification process  
10 is invoked. Otherwise, the method updates internal texture pixels (step 506) and ensures all the other polygons if there are any not processed yet (step 507). The pixel intensity modification process consists of three steps: Firstly, a pixel, p, is extracted from the boundary (step 503). The method searches another image point in neighboring plaque textures that is closest to the boundary pixel p. The pixel intensity of the boundary image  
15 point is set to be weighted average of the two (step 504). The pixel intensities before and after the adjustment are recorded so that the difference can be used to adjust the intensities of other pixels inside the polygon (step 505). The pixel intensity adjustment inside the polygon is done using the following formula:

$$T'_s(x, y) = T_s(x, y) + \sum_{i=1}^N w_i \cdot Id_i$$

20 where  $w_i$  is a relevant weight;  $Id_i$  is the adjusted difference; N is the number of total adjustments;  $T_s(x_i, y_i)$  is the pixel intensity of each point on the 3D model; and  $T'_s(x_i, y_i)$  is the adjusted pixel intensity of each point on the 3D model.

In the above formula, we may use the pixel intensity difference of a single (N=1)  
25 nearest boundary pixel or pixels on different boundaries (N = the number of sides in a polyhedron). This helps achieving smooth visual effects. The color and brightness variations between two regions can be eliminated.

Certain variations would be apparent to those skilled in the art, which variations are considered within the spirit and scope of the claimed invention.